Creating a Bespoke Virtual Reality Personal Library Space for Persons with Severe Visual Disabilities

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ABSTRACT

We present our work on creating a virtual reality personal library environment to enable people with severe visual disabilities to engage in reading tasks. The environment acts as a personal study or library to an individual, who under other circumstances would not be able to access or use a public library or a physical study at home. We present tests undertaken to identify the requirements and needs of our users to inform this environment and finally present the working prototype.

CCS CONCEPTS

• **Information systems** → *Multimedia information systems*; • **Human-centered computing** → **Accessibility systems and tools**; **Accessibility technologies**; • **Hardware** → *Emerging technologies.*

KEYWORDS

Virtual Reality, VR, Visual Disabilities, Library, Reading

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1 INTRODUCTION AND MOTIVATION

The idea of a virtual reality library has been considered for decades [5, 6]. The digital dimension that libraries can benefit from, include more than solving technical constraints, such as storing a large amount of books, or not being able to check out an already loaned book; but more-so, an ability to get users to engage with library services, or as one author puts it "the basic drive is to get people back into the library"[7]. This statement is accentuated and highlighted when the key factor to being able to read content is not simply a case of motivation, but one of accessibility. In our work, we focus on the needs of users with severe visual disabilities. Such ones, suffer from mobility issues - unable to get to a library - as well as limitations in reading capability once they have access to a physical artefact, such as the book. We endeavour to accommodate an 'as authentic as possible' experience, to having a personal library space and reading environment, using virtual reality. The environment needs to be bespoke in that the reader application as well as the surroundings need to facilitate the requirements and specific needs of our user group. In order to develop this environment we perform tests in virtual reality with purpose built surroundings, to inform our final application. The next section presents the testing environments that we used to understand the preference and visual acuity of our end-users, as well as the findings from a user test. We then present the initial build of our virtual private library room. We finish the paper with a future work section.

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2 TESTING ENVIRONMENTS

In order to begin designing a suitable environment for our specialised reading space, we created testing grounds to immerse our end-users and understand their preferences as well as abilities. The reason for this is to be able to accommodate for as natural a setting as possible, however realising and accepting that an exact replica of a real environment is not only unrealistic, but also not useful for the specific needs of our end-user group. We present findings from three tests in three unique environments (after an initial callibration test). Before presenting these we report on the participants recruited to take part in the experiments. All environments were created using the Unity[8] platform and the tests carried out using an Oculus Rift CV1 head mounted display[4].

2.1 Participant Selection

For our study we recruited 8 participants who were service users of a facility that provides support for people with severe visual disabilities. These participants were all classed as being "Low Vision"[1], and all were supported in some way in their daily lives due to their visual disabilities. These users had an array of different conditions (e.g. Macular Degeneration/Glaucoma/Diabetic Retinopathy), so there was no particular focus on specific conditions or acuity levels. In order to conduct these tests, ethical approval was obtained prior to testing and participant consent was given.

2.2 Calibration Scene

Prior to testing, the Oculus Rift CV1 must be calibrated to each individual's Interpupillary distance (IPD). By default the Oculus Rift CV1 has its own calibration tool, yet the tool lacks any ability for customisation or configuration. This scene (See Figure 1) was designed around said tool, but improved upon so that the environment can be manipulated to test for multiple distances and the users view is not locked to avoid issues with conditions like Macular Degeneration (central vision loss).

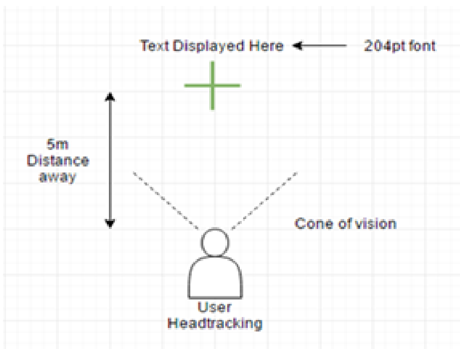

Figure 1: The calibration scene

2.3 Text Distance

This test (See Figure 2, 3) was designed to get an early measurement of what kinds of reading ability visually impaired users may have within a VR HMD at various levels of distance. As we can manipulate the environment to display information within a digital space, we needed to gauge whether severely visually impaired users would be able to see and observe 3D text from various distances, as well as the suitability of how information might be presented to them. Users were asked to keep their head still while facing forward while attempting to read several passages using white font in a darkened 3D environment. The background surrounding was made a black gradient, but not absolute, to emphasise the 3D space. Distance from the participant and the text was set to 1.5m by default with a 100pt font size for text. If the participant cannot read the text, the distance is decreased until that participant can read, otherwise a new passage of text is presented at an increased 1.5m distance.

Results showed that all but 1 participant struggled with the default distance of 1.5m and needed the text to be closer to them for increased clarity. 1 participant could read at 1.31m, 2 participants could read at 1m, while 3 required a distance of 0.7m. Our final participant could not read at any distance up to 0.5m. One participant commented that the background gradients were distracting. We also acknowledge that 3 participants struggled to read the text even at the 0.7m distance at 100pt font, so the ability to customise font, the background, and how text is displayed is crucial for tailoring around accessibility, as just adjusting size/distance is insufficient for readability.

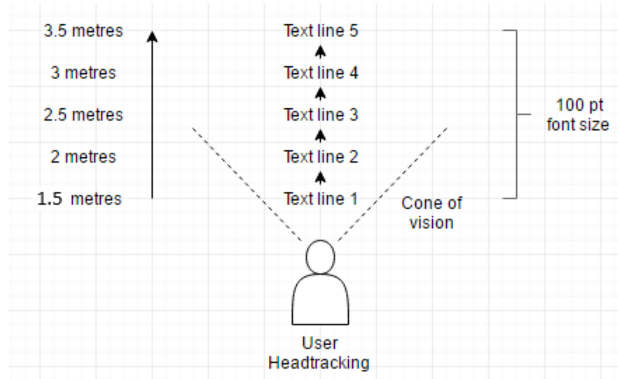

Figure 2: Text Distance Diagram

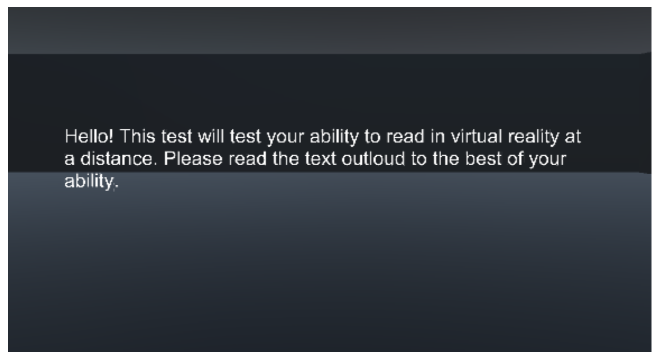

Figure 3: Text Distance Unity Scene

2.4 Coloured Text Test

In order to determine how participants might observe coloured signs and labelling, and more specifically emulate potential categorisation labelling of bookshelves within a room setting (such as a library would have), we created an environment to test the ability of participants to be able to read coloured text located on walls around them. A scene was devised (See Figure 4, 5) to observe each participant's ability to recognise static words of varying colour in contrast to 4 different coloured walls. This coloured text is 2D, as opposed to our distance and calibration scenes which have floating 3D text. The user is centred between these 4 coloured walls covered in texts. Different texts are displayed, all at 100pt font, with selected colours that either contrast well against each background's wall, or poorly, to determine whether participants could read texts of similar colour shades, or vastly contrasting. Users were allowed to freely move their head in this scene and were asked to rotate around within 360 degrees while being asked to identify and read out whatever texts they could see along with what colours they thought they were. Text and colours were the same for each user, and varied in brightness values to appear more or less contrasting to their background colour.

Participant results were promising in this test, with all participants being able to read to some degree despite the visual noise of the scenery. This is contrasting to the previous Distance text test, where text at the same font size and shorter distances was more

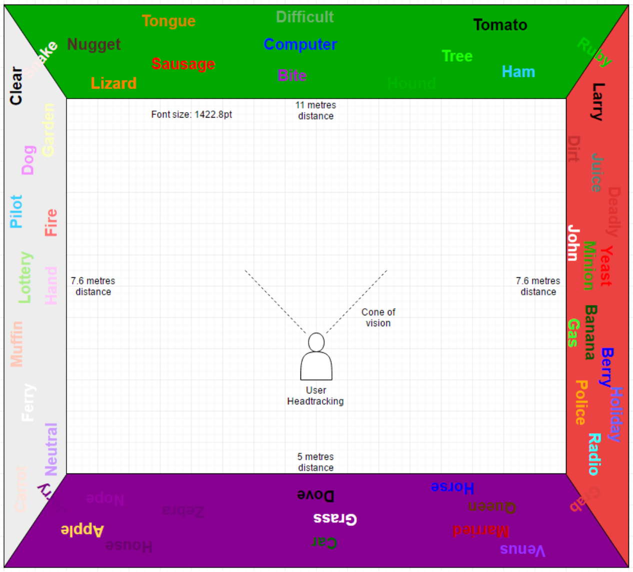

Figure 4: Coloured Text Diagram

Figure 5: Coloured Text First Person Perspective

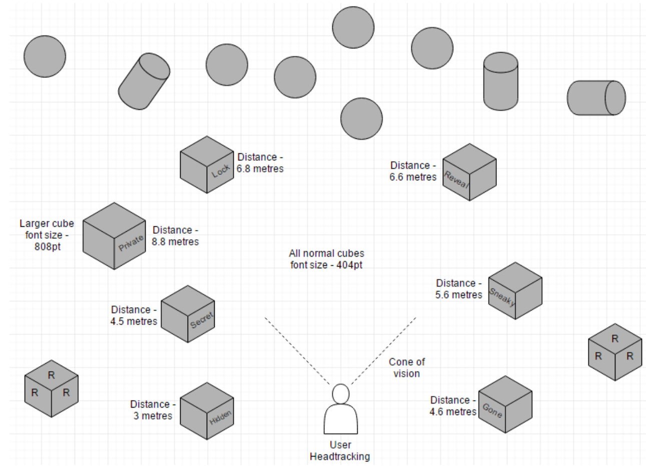

Figure 6: Brightness Text Test Diagram

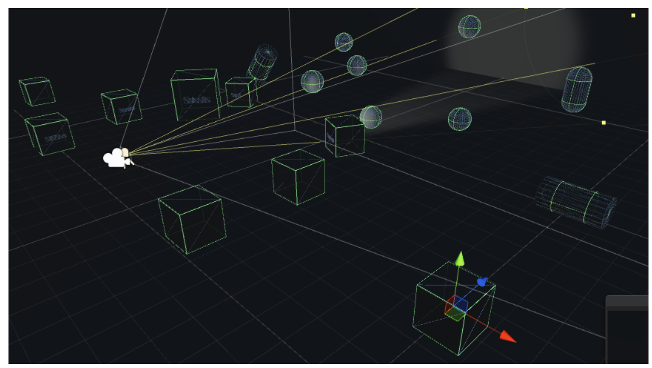

Figure 7: Brightness Text Test Unity Scene

difficult to read. Most participants preferred reading from the red or green backgrounds, while white and purple backgrounds were less clear. Participants responded positively to this test and were impressed with their ability to read and perceive multiple colours. This test shows the requirement for different accessibility colours, as participants that could not read text on black/white contrasts could read some texts of varying colours when the backgrounds were red or green, and allowing for multiple colours will be essential for our software.

2.5 Brightness Text Test

The Brightness Text scene (See Figure 6, 7) was designed to test whether participants could recognise text within a darkened environment using a flashlight of various radius and position. First we wanted to be able to observe how low visually impaired users would react to a lower light environment, as some conditions cause bright lights to blind or discomfort the eyes. Secondly this test allows us to observe the capability of a low light environment, where users may want to dim or disable lights so they can view books in a environment with little background noise. Users were asked to face forward within the environment while a flashlight was activated. This flashlight followed the user's central vision, and could be manipulated via head motion, change its radius, or its angle. This scene was particularly useful in viewing how Macular Degeneration users would utilise the flashlight to best illuminate the environment. Various configurations would be tested alongside the participant's feedback, while they were asked whether they could describe what they could see and whether they could read presented words.

Brightness test results showed that 5 participants could read all words presented, while 3 could only read between 1-2 words after adjustments were made. All participants responded verbally positive to an increase in light levels in the scene, some requiring these increases to be able to detect any words. One participant with Macular could only see half of each word, but increasing the brightness greatly helped their visual clarity. Distances here were a lot more varied, but all participants could read the closest word at 3m distance. These results show that the ability to manipulate brightness are crucial for our application.

Figure 8: The software with 3 books selected

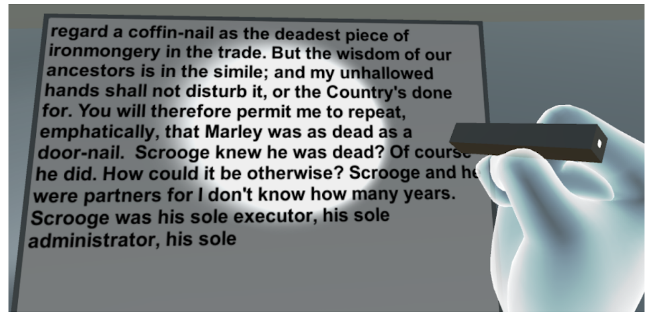

Figure 9: Text loaded with the flashlight enabled for reading

3 SOFTWARE DESIGN & PROTOTYPE

The software developed was created using the Unity platform, alongside a Oculus Rift CV1[4] for testing. Both the application and VR headset is run alongside a laptop that allows for fine control of the environment via keyboard as well as the ability to record all data live as a user navigates the software. This prototype is being developed alongside the feedback gathered from testing from participant results and interviews. The application allows for the user to use a custom environment designed around a library environment, with books that can be selected to be read from (See Figure 8). Book models only represent what can be chosen, as text is displayed upon a floating panel and can be held like a tablet(See work in [9]), rather than displaying the text on the book itself. A flat panel was chosen over a book due to participant feedback from the Text distance test indicating that users need to be able to customise the background and fonts very specifically, which is best done on a flat plane to reduce noise. Additionally the panel was chosen due to the increased complexities of translating real world interactions to a virtual controller, as precise movements such as individual finger grabbing of pages cannot be done[2] with our chosen VR setup, which may have been confusing to our users.

Based on feedback from our test group, reading equipment needs to be as simple as possible, as additional visual noise will often decrease acuity for people with severe vision loss. As such, our environment keeps many key graphics very simple, with the option to disable background assets and display only the reading tablets desired. The goal of this software is to create a personalised space that the user can customise to their preferences or needs, so modular design is fundamental. The current prototype application allows for users to download books from Project Gutenberg[3] to be displayed as a text panel to a assigned book, or choose from a selection of pre-installed sample books. Black enlarged font on a light grey background was selected as the default view for books as a safe baseline, but the ability to change background, panel, border, and text colours are possible by the user and can be saved as their new default based on their feedback from our Colour text test. Brightness also needs to be adjustable dynamically depending on the users preferences, as highlighted in our brightness test, so lights may be enabled or disabled from different sources and a pocket torch can be activated to shine light from any angle or direction the user prefers (See Figure 9). The participant can move books with virtual motion controlled hands via Oculus controllers, but to make changes to either the environment or each book voice commands are used instead, to simplify the control scheme.

4 SUMMARY AND FUTURE WORK

In this paper we presented a Virtual Reality Personal Library, tailored for persons with severe visual disabilities. The fully working prototype was developed based on a user-centred design approach and through testing of three individual environments, custom made for us to identify needs from the users. We are currently performing further testing on our system, to identify factors such as its usability, its adoption by users and its potential, using qualitative measures, such as optometry based tests to compare the VR system to physical alternatives and qualitative means for the usability tests. Preliminary findings suggest that the system is usable, well received and given the ability to people that have not being able to read textual material for several years, the opportunity and motivation to do so again. We have also had further requirements, such as to add multimedia capabilities within the personal library environment, like videos. We are currently testing requirements to integrate a video wall in the environment. Lastly, we are also experimenting with the opportunity for users to use the headset to scan pages within books using optical character recognition in real time, which will then be presented to them in our reading environment, allowing for an even more authentic experience and feel of reading as well as personalised accessibility. This will also allow users to not be confined to the material that our environment has to offer.

5 ACKNOWLEDGEMENTS

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